A Field Sequential Color LCD Base on Color Field Arrangement for Color Breakup and Flicker Reduction

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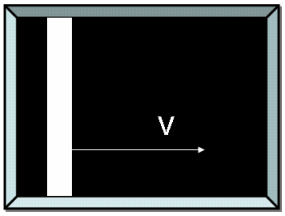
Abstract

Field sequential color liquid crystal displays (FSC-LCDs) have several original benefits, including higher light efficiency, definition, and color saturation than those of conventional LCDs. However, FSC-LCDs are well known that the color breakup (CBU) is the serious issue needed to be solved. We have developed a new driving technique on a 5.6-inch OCB mode FSC-LCD. This proposed 4-color field arrangement (4-CFA) method can effectively eliminate the CBU of FSC-LCDs.

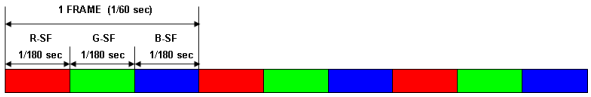
1. Objective and Background

It is well known that the most serious issue of FSC displays is "color breakup (CBU)" artifact: if a displayed object is moving on an FSC display, its leading and trailing edges appear in rainbow colors. The intrinsic visual artifact, CBU, has shown to degrade visual quality. For example, a white bar with black background moves on a conventional FSC-LCD, as shown in Fig. 1(a). The color sequence with frame frequency of 60 Hz is shown in Fig. 1 (b). The arrow A indicates the shift of the observer's viewpoint in time and location of motional image of RGB sub-frame as shown in Fig. 1 (c). The observer will recognize an image as shown in Fig. 2. The margin area has color separations due to the relative motion between eyeball and images. Consequently, the CBU of fast-motional image becomes a main issue of FSC-LCDs. For improving the image quality on the FSC display, several methods have been proposed to improve the CBU on FSC display. These proposals could be categorized as (1) field rate increasing [1-2], (2) multi-primary color fields [3-4] and (3) motion compensation [5]. However, the first two methods require high frame rate (300~360 Hz). That has limitation in response time of LC. The motion compensation method has a problem while the eyes trace in opposite direction and two moving objects are displayed at the same time. These methods are only effective in particular cases.

In this paper, we propose a method to reduce the CBU phenomenon and avoid flicker. The proposed driving scheme can be adopted in current TFT and LC limitations.



(a)



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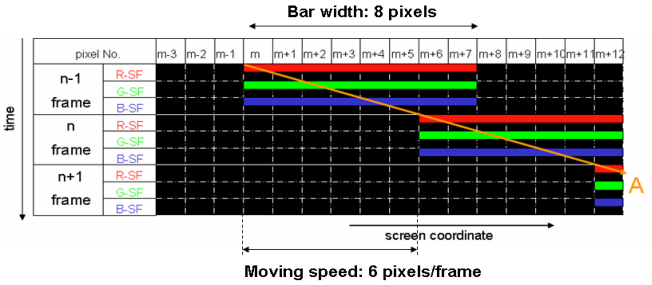

(c)

Fig. 1 (a) Schematic plot of a white color bar motional image on display (b) RGB color sequence of FSC displays (c) Relation between time and location of motional image on retina

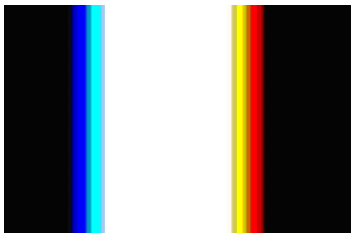

Fig. 2 Perceiving CBU image.

2. Novel Proposed CBU Reduction Method

2.1 Color Field Arrangement Method

Base on a CBU reduction method, called color fields arrangement (CFA) method, was proposed by T. Makini, T. Yoshihara, H. Shiroto, and Y. Kiyota [7]. The color sequence is shown in Fig. 3(a). In three consecutive frames, the primary color of each sub-frame is different from the other two. The two dimensions time and location diagram is shown in Fig. 3 (b), which shows a model of a white bar on display as Fig. 1 (a). In three consecutive frames, the tracing path of eyes goes through the same ratio of each primary color. The image on retina will be compensated as the different gray levels without CBU, as shown in Fig. 4. The comparisons of perceiving image between conventional and CFA method are shown in Fig. 5.

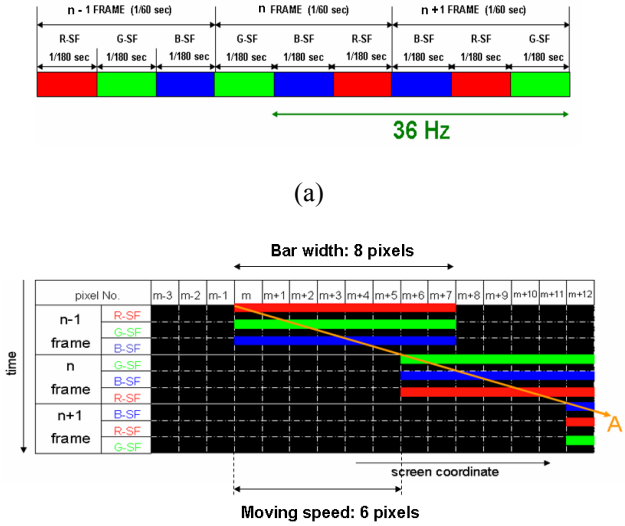

Fig. 3 (a) Color field with RGB, GBR and BRG (b) Relation between time and location of motional image.

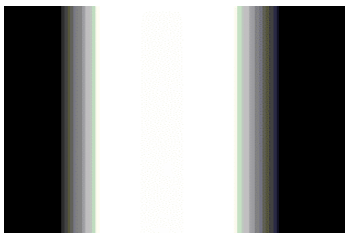

Fig. 4Perceiving CBU image

2.2 Issue of Color Field Arrangement Method

According to the flicker report [6], the lowest field frequency to prevent flicker for three primary, red, green, and blue color are 30Hz, 50Hz, and 35Hz respectively. The field frequency below these thresholds will result in static flicker phenomenon due to the temporal variation in chromaticity. Because the human eye is more sensitive to the green color, the lowest field frequency for green color to perceive invisible flicker is 50Hz. As the proposed CFA method, the field frequency for green color is 36Hz only. It causes static flicker phenomenon.

2.3 4-Color Field Arrangement Method

Consequently, we propose a 4-color field arrangement (4-CFA) method to suppress the flicker phenomenon. It still performs as original CFA method to eliminate CBU of dynamic image but the field rate is only 240 Hz. The color fields with order of RGBR, GBRG, and BRGB in three consecutive frames, color of the forth sub-frame repeats the color of the first sub-frame, is shown in Fig. 6. The LED lighting duty is arranged to keep the correct white balance. The flicker phenomenon is eliminated due to the 80 Hz sub-frame frequency.

3. Physical Evaluation Results of CBU

After demonstrating a non-flicker FSC-LCD with the 4-CFA method, a psychophysical experiment of the CBU phenomenon was evaluated. Fig. 7 is a photograph of a 5.6-inch OCB panel with 4-CFA driving method. The perception of CBU was evaluated to verify the proposed CBU reduction method.

We chose a test pattern to be the most critical viewing condition to maximize its perception. Such as a moving white bar image in the black background was used. The evaluation results of the conventional driving method and 4-CFA driving method with three different image colors, white, cyan, and red, and three moving velocities of the object are shown in Table. 1. From the evaluation results, the CBU in 4-CFA driving method was eliminated and independent to the image color and moving velocity.

4. Conclusions

A color field arrangement (CFA) method was proposed to suppress the CBU phenomenon effectively. Color separations will be invisible at the margin area by using the CFA method. However, in this original proposed CFA method may result in static flicker phenomenon due to the temporal variation of the green color. Therefore, the modified 4-CFA method was proposed to suppress the static flicker phenomenon and can maintain invisible color separation at the margin area. The field rate of the proposed 4-CFA is only 240Hz and both the flicker and CBU were eliminated. This proposed method was also implemented and verified on a 5.6-inch OCB FSC-LCD.

5. Acknowledgements

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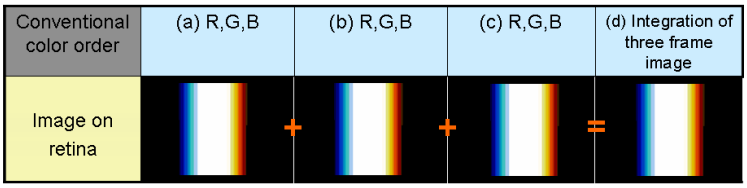
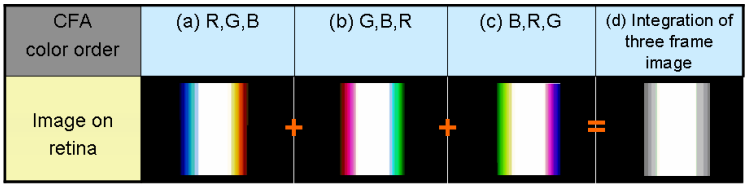


(a)



(b)

Fig. 5 Observer recognizes an image in three continuous frame.(a) Conventional color order (b) CFA color order.

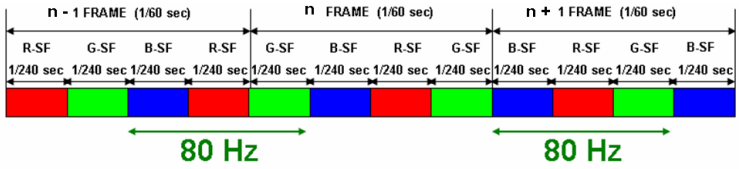


Fig. 6 Color field with order of RGBR, GBRG, and BRGB in three consecutive frames

Fig. 7 Photograph of the LCD demonstration

Table. 1 Comparison table of moving image

image color \ Velocity (pixels/frame)			1	2	3	4	5
White bar W=15 pixels 	4-CFA	Blur (pixels)	x	1	2	2	3
		CBU	x	x	x	x	x
	Conventional RGB	CBU (pixels)	1	2	2	2	4
Cyan bar W=15 pixels 	4-CFA	Blur (pixels)	x		1		x
		CBU	x		x		x
	Conventional RGB	CBU (pixels)	1		1		2
Red bar W=15 pixels 	4-CFA	Blur (pixels)	x		x		x
		CBU	x		x		x
	Conventional RGB	CBU (pixels)	x		x		x